Findlay, W.P.K. & Pettifor, C.B

1941

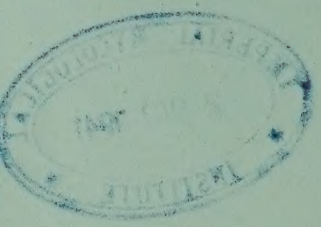
IMPERIAL MYCOLOGICAL INSTITUTE
2 OCT 1941

Reprint from the

EMPIRE FORESTRY JOURNAL

Vol. 20, No. 1, 1941

INTERNATIONAL MYCOLOGICAL INSTITUTE LIBRARY
29 JAN 1992
FINDLAY, W.P.K.



RESEARCH NOTES

DARK COLORATION IN WESTERN RED CEDAR IN RELATION TO CERTAIN MECHANICAL PROPERTIES

By W. P. K. FINDLAY, M.Sc., and C. B. PETTIFOR, B.Sc.
(*Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.*).

SUMMARY.

(1) The strength properties of samples of Canadian Western red cedar heartwood possessing a dark brown colour have been compared with those having the normal light colour. It was found that the dark-coloured heartwood was less tough, softer and weaker in compression than the normal light-coloured heartwood, the reduction in each of these strength properties being about 20 per cent. The dark material had also lower specific gravity than the light, this difference in specific gravity being closely correlated with the difference in strength.

(2) Fungus mycelium was almost invariably present in the darker wood and absent in the light-coloured wood.

(3) It is concluded that the dark coloration, lower specific gravity and reduced strength properties are brought about by fungal attack.

(4) The fungal hyphae were observed to have penetrated the cell walls in the manner described as typical of *Poria weirii*, but definite identification of the fungus present was not possible, and the alterations observed may be brought about by a fungus of the staining type.

INTRODUCTION.

THE heartwood of Western red cedar (*Thuja plicata* D. Don.) varies greatly in colour, and Eades and Alexander (1934) state that the variation in colour in this species is greater than in any other commercial timber species of British Columbia.

This variation in colour has given rise to a prejudice against some of the dark-coloured material, which is reputed to be more brittle and less durable than the normal lighter-coloured wood. In order to ascertain whether this trade bias against the dark-coloured material had any basis in fact, Eades and Alexander (1934) undertook an investigation in order to determine to what extent colour could be taken as a criterion of quality, both in regard to strength and durability. Their conclusion was that the strength properties of light- and of dark-coloured heartwood are practically identical, but they found that whereas the light-coloured heartwood was on the whole free from micro-organisms, the dark heartwood often contained them. Since, however, no wood-destroying fungi could be detected, they decided that the matter was of academic rather than of practical significance. They concluded that the dark colour did not connote decay, and that coloration alone is a poor, and in fact a useless guide, in choosing material with a view to securing maximum durability or strength.

In the course of a study of the natural resistance to decay of this timber, it was observed that test blocks prepared from the dark-coloured heartwood appeared to be more susceptible to attack by certain decay-producing fungi such as *Coniophora cerebella* than were those cut from light-coloured heartwood, and that while it was with great difficulty that fungus mycelium could be induced to grow at all over the light-coloured samples, much less difficulty was experienced with the dark-coloured ones. In consequence it was considered that the subject deserved further study, of which this report gives the results.

Material for Test.

Inspection of stocks of Western red cedar held at the Laboratory showed a number of planks with considerable range of colour, and a selection from these was made as follows :

SELECTION OF PLANKS.

Plank No.	Approximate Cross Section	Coloration	Length taken
1	9 inches × 4 inches	Clear bright pinkish shade	Approx. 30 inches
2	9 inches × 3 inches	Light with dark streaks	30 inches
3	4 inches × 3 inches	Light and dark material somewhat irregularly distributed	9 feet
4	9 inches × 3 inches	Dark at one end. Relatively light at other	30 inches from each end

The ring width throughout these planks was fairly uniform at about 0.05 inch (twenty rings to the inch), although extreme values of 0.02 inch to 0.07 inch (fifty-fourteen rings per inch) were found at a few points.

Properties Investigated and Methods of Testing.

The planks, already seasoned to about 10 per cent moisture content, were cut into sticks about 15 inches long, which were planed to $\frac{5}{8}$ inch square, with the sides truly radial and tangential. Each stick provided one test-piece for determination of each of the following properties.

No colour discrimination was made until after test.

Toughness. A standard test-piece 10 inches long and $\frac{5}{8}$ inch square, freely supported over a span of 8 inches, was broken by a single blow in an impact machine of the pendulum type, the energy absorbed in fracturing the test-piece being taken as a measure of its toughness. The blow was delivered in a direction parallel to the annual rings, i.e., on a radial face.

Maximum Compressive Strength. The test-piece used was $2\frac{1}{2}$ inches long and $\frac{5}{8}$ inch square.

Hardness. Tests for hardness were made on the radial and tangential faces of the lightly stressed ends of the toughness test-piece after test. Owing to the small dimensions, a sub-standard hardness tool was used in which the radius of the hemispherical end was 0.111 inch, i.e., half the standard radius. Since the results were comparative only, no conversions to equivalent values for the standard tool were made.

Moisture Content. The moisture content, based on the oven-dry weight of the wood, was determined for each test-piece.

Nominal Specific Gravity. Each test-piece was weighed immediately before test, and from this weight and its moisture content, the value of the nominal specific gravity, based on the oven-dry weight and volume at time of test, was determined.

Classification by Coloration.

After test, the test-pieces were divided into five colour groups, ranging from the darkest to the lightest. The colours of these groups, based on the Ridgway colour standard, were as follows :

Group 1—darkest .. .. cinnamon brown
Group 2—intermediate (pinkish brown) .. army brown / fawn colour
Group 3—intermediate (yellowish brown) .. sayal brown
Group 4—light .. .. onion skin pink
Group 5—lightest .. .. buff pink

There was of necessity no sharp line of demarcation between the various groups, and colour distinction between adjacent groups was, in general, only possible by direct comparison ; uncertainties in classification also arose with many test-pieces of non-uniform colour. It was subsequently decided to limit the number of groups to three only, by amalgamating Nos. 2 and 3 as intermediate, and Nos. 4 and 5 as light.

After test and colour classification, the test-pieces were examined for the presence of fungi.

Mycological Examination.

Sections taken as near as possible to the point of fracture were cut from representative test-pieces in each group. They were stained in picro-aniline blue and safranin, and examined under the microscope. All the samples examined in the dark group were found to contain fungus mycelium in varying amounts. Most of the hyphae observed passed in a straight line through a number of cell walls, the hyphae being somewhat restricted at the bore holes. This method of penetration of many cell walls in line is stated by McCready (quoted by Boyce, 1938) to be typical of *Poria weirii*, which is a well-known cause of heartrot in Western red cedar.

All the test-pieces in the Group 2 (army brown and fawn colour) were sectioned and fifteen out of forty-eight were found to contain fungus in varying amounts. Variations in colour occur naturally in this timber, and it is not easy to pick out samples which may be considered as abnormal unless the coloration is very pronounced. It will be noted that the strength and specific gravity values for the intermediate colour group fall between those for the dark and for the light group.

In none of the light-coloured samples which were examined (Groups 4 and 5) was any trace of fungus found.

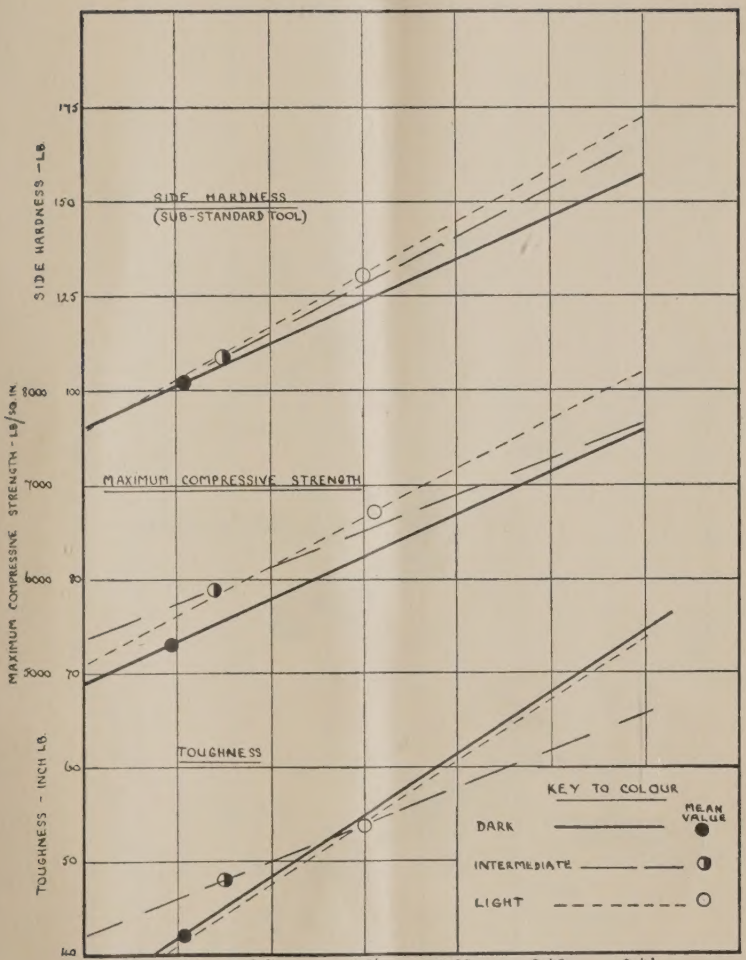
Discussion.

Table 1 gives the mean values of the different properties for the three colour groups, the figures in brackets denoting the percentage of the corresponding figure for the light normal timber (Groups 4 and 5).

The results show that there is a consistent decrease in the properties under consideration as the colour changes from light through intermediate to dark ; these decreases are of the same order for the three strength properties examined, i.e., 11-16 per cent decrease for the intermediate colour, and 22 per cent for the dark colour. This result is rather surprising, since it is usually found that where fungus attack affects strength properties at all, the toughness is reduced to an appreciably greater extent than such properties as hardness and compressive strength.

In general, most strength properties decrease with decreasing specific gravity, and it is of interest to examine the results in greater detail, to determine whether or not the lower strength values of the darker material might not be attributable to its lower density. Accordingly, for each colour group, the correlation co-efficients between nominal specific gravity and the three strength properties in turn were calculated, and from these the regression lines showing the relationship between strength and specific gravity were drawn. Table 2 and Figure 1 give the results of this analysis.

The three regression lines for each property do not show any appreciable divergence considering the limited number of results used for their determination. Thus the estimated strength value for light material at the average nominal specific gravity of the darker timber would not differ appreciably from actual experimental values obtained for this timber. The most marked difference was shown for maximum compressive strength, but even for this property the difference was not great. Thus it may be concluded that the lower strength values of the darker timber could be accounted for by the lower specific gravity, so that the factor responsible for the dark colouring appears to be responsible also for the reduction in specific gravity and consequent reduction in strength. There was, however, no evidence that the darker-coloured timber occurred in such positions in the growing tree that lower specific gravity values might normally be expected. This was brought out by

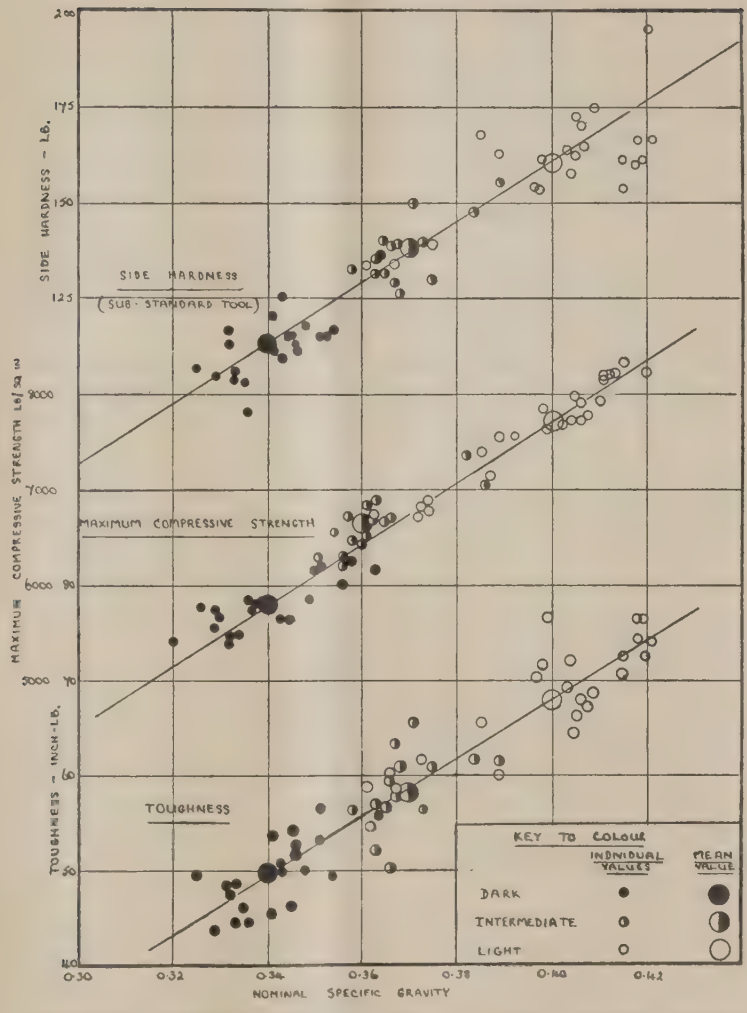


REGRESSION LINES SHEWING STRENGTH — NOMINAL SPECIFIC GRAVITY RELATIONS FOR WESTERN RED CEDAR

FIG: 1

detailed examination of the results for plank 3, in which the dark coloration occurred in patches irregularly distributed over the cross-section and down the length of the plank, and was not therefore associated with any particular position in the growing tree. The mean values for this plank, which was of higher density than the others, are given in Table 1 (*b*). Individual test results in relation to nominal specific gravity are also shown in Figure 2.

For each property these results are grouped about a straight line passing approximately through the three mean values for the colour groups. Except for a slight



COLOURATION IN WESTERN RED CEDAR AS RELATED TO CERTAIN MECHANICAL PROPERTIES

PLANK 3
FIG. 2

intermingling in the intermediate colour group (which, in view of the fact that there is no sharp line of demarcation between the colour groups, is not surprising), the strength properties and nominal specific gravity decrease correspondingly as the colour changes from light to dark.

Thus it was concluded that the darker material was associated with lower values of nominal specific gravity and correspondingly lower strength values.

Since it was found that the dark-coloured test-pieces almost invariably contained

fungus mycelium in varying amounts, while the light-coloured test-pieces were entirely free from fungus, and that some of the intermediate test-pieces contained hyphae, it may reasonably be concluded that the dark colour and reduced strength are associated with the presence of fungi. Eades and Alexander were, in fact, able to isolate quite a number of fungi, stating that "the prevalence of moulds and *fungi imperfecti* (unaccompanied by wood-destroying fungi) was remarkable in the dark heartwood, but they were almost entirely absent in the light heartwood". Only in a few isolated cases were typical wood destroying fungi found in their cultures. It is, however, often extremely difficult to isolate rather slow-growing wood-rotting fungi from durable timbers, such as Western red cedar, and the absence of these fungi from cultures does not necessarily mean that they were absent in the samples of wood from which the cultures were made.

Examination of the results for the light and dark ends of plank 4 showed that, in certain cases, test-pieces taken from corresponding positions in the cross-section of the two ends had markedly different toughness values. Pairs of such test-pieces were selected for mycological examination, the results being given in Table 3. It is striking that although the lighter-coloured test-pieces were assigned to the intermediate colour group, in no case was the presence of fungi detected, whereas in every case the matched dark test-piece, having a lower toughness value, showed the presence of fungi, more or less abundantly distributed. The association of the presence of fungi with the darker timber and with lower toughness values is thus emphasized.

In view of the statistically significant differences in strength between dark- and light-coloured heartwood, and the almost invariable association of fungi with the dark-coloured material, it seems probable that the fungi are *responsible* for the dark coloration and reduced strength and specific gravity.

It is not possible without examination of further material to determine what species of fungus is primarily responsible. There are two possibilities, either the dark coloration is caused by the early stage of attack by a wood-rotting form causing a heartrot of the living tree, or it is due to the action of one or more species of "staining" fungi. It has been shown by the authors that certain staining fungi may appreciably reduce toughness and hardness. The fact that the maximum compression strength also is found to be appreciably lower in the dark than in the light wood rather suggests that a wood-rotting fungus may be at work, though certain staining fungi, such as *Botryodiplodia*, have been found by the authors (1939) to reduce bending strength. As stated above, the hyphae seen in the wood resemble those of a fungus (*Poria weirii*) known to attack the timber in question. It is therefore suggested until further evidence is available that the dark coloration should be regarded as an incipient stage of rot, which possibly is accompanied by fungi of the staining type.

The work described in this paper was undertaken as part of the programme of the Forest Products Research Board, and is published by permission of the Department of Scientific and Industrial Research.

REFERENCES.

Boyce, J. S. (1938) : *Forest Pathology*. McGraw-Hill Book Co., London, 1938.

Eades, H. W., and Alexander, J. B. (1934) : "Western Red Cedar : Significance of its Heartwood Colorations". Dept. Int., Canada. Forest Service Circular **41**, 17 pp.

Findlay, W. P. K., and Pettifor, C. B. (1937) : "Effect of Sapstain on the Properties of Timber. I. Effect of Sapstain on the Strength of Scots Pine Sapwood". *Forestry* **II**, 40-52.

Findlay, W. P. K., and Pettifor, C. B. (1939) : "Effect of Blue Stain on the Strength of Obeche (*Triplochiton scleroxylon*)". *Emp. For. J.*, **18**, 259-267.

TABLE 1

COLORATION IN WESTERN RED CEDAR AS RELATED TO CERTAIN MECHANICAL PROPERTIES

(*a*) ALL RESULTS

Coloration		Toughness Tests				Compression Tests				Hardness Tests			
Group	Ridgway Colour Standard Nomenclature	Number of Results	Moisture Content per cent	Nominal Specific Gravity	Energy Absorbed inch lb.	Number of Results	Moisture Content per cent	Nominal Specific Gravity	Maximum Compressive Strength lb./sq. in.	Number of Results	Moisture Content per cent	Nominal Specific Gravity	Side* Hardness lb.
1 Dark	Cinnamon brown	64	10.4	0.32 (89)	42.1 (78)	64	9.2	0.32 (89)	5320 (79)	64	8.2	0.32 (89)	102 (78)
2 and 3 Intermediate	Fawn .. .. Army brown .. Sayal brown ..	67	9.9	0.33 (92)	48.0 (89)	68	8.7	0.33 (92)	5900 (88)	67	7.8	0.33 (92)	110 (84)
4 and 5 Light	Onion skin pink Buff pink ..	98	10.2	0.36 (100)	54.1 (100)	65	9.4	0.36 (100)	6730 (100)	95	8.3	0.36 (100)	131 (100)

(*b*) PLANK 3 ONLY

1 Dark	Cinnamon brown	21	10.7	0.34 (85)	49.8 (73)	20	9.4	0.34 (85)	5790 (76)	21	8.4	0.34 (85)	113 (70)
2 and 3 Intermediate	Fawn .. .. Army brown .. Sayal brown ..	14	10.7	0.37 (92)	58.6 (86)	15	9.2	0.36 (90)	6650 (87)	14	8.4	0.37 (92)	138 (86)
4 and 5 Light	Onion skin pink Buff pink ..	24	10.5	0.40 (100)	68.0 (100)	24	9.2	0.40 (100)	7660 (100)	22	8.4	0.40 (100)	161 (100)

* *Sub-standard tool.*

TABLE 2

COLORATION IN WESTERN RED CEDAR

RELATIONSHIPS BETWEEN STRENGTH AND NOMINAL SPECIFIC GRAVITY FOR DIFFERENT COLOUR GROUPS

	Toughness			Maximum Compressive Strength			Side Hardness		
	Group 1 (Dark)	Groups 2 and 3 (Intermediate)	Groups 4 and 5 (Light)	Group 1 (Dark)	Groups 2 and 3 (Intermediate)	Groups 4 and 5 (Light)	Group 1 (Dark)	Groups 2 and 3 (Intermediate)	Groups 4 and 5 (Light)
Number of Results	64	67	98	64	68	65	64	67	65
Mean Strength Value	42.1 inch lb.	48.0 inch lb.	54.1 inch lb.	5320 lb. per sq. inch	5900 lb. per sq. inch	6730 lb. per sq. inch	102* lb.	110* lb.	131* lb.
Mean Nominal Specific Gravity	0.32	0.33	0.36	0.32	0.33	0.36	0.32	0.33	0.36
Correlation Co-efficient between Strength and Nominal Specific Gravity ..	0.84	0.70	0.89	0.92	0.94	0.97	0.85	0.94	0.92
Increase in Strength for 0·1 Increase in Nominal Specific Gravity	32.9 inch lb.	19.8 inch lb.	33.8 inch lb.	2250 lb. per sq. inch	1940 lb. per sq. inch	2600 lb. per sq. inch	55 lb.	64 lb.	70 lb.

* *Sub-standard tool.*

TABLE 3

COLORATION IN WESTERN RED CEDAR

COMPARISON OF DARK AND LIGHTER TEST-PIECES FROM PLANK 4

(MATCHED FOR POSITION IN THE CROSS SECTION)

Dark End of Plank				Lighter End of Plank			
Colour Group	Nominal Specific Gravity	Tough-ness inch lb.	Results of Mycological Examination	Colour Group	Nominal Specific Gravity	Tough-ness inch lb.	Results of Mycological Examination
Dark	0.30	37.8	Fungus present—not abundant	Intermediate	0.32	51.3	Clear
,,	0.30	31.2	Fungus present—moderately abundant	,,	0.30	44.8	,,
,,	0.32	33.9	Fungus plentiful	,,	0.32	52.5	,,
,,	0.30	34.3	Some fungus in one test-piece, moderately abundant in other	,,	0.32	46.0	,,
,,	0.30	34.5	Fungus plentiful in one test-piece; present but not plentiful in other	,,	0.32	49.1	,,
,,	0.30	37.3	Fungus present, but not plentiful	,,	0.31	47.6	,,
,,	0.31	42.5	Fungus present, but not abundant..	Light	0.31	53.9	,,

PRINTED IN GREAT BRITAIN BY
OXLEY & SON (WINDSOR) LTD.
PRINTERS BY APPOINTMENT TO
HIS MAJESTY THE KING
4 HIGH STREET, WINDSOR